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Figure **Title**

73-2.0 THREE-SIDED DRAINAGE STRUCTURES

These guidelines should be used for a Department-maintained route project or a federally funded local public agency project.

73-2.01 Structure Sizing and Selection

If the project is on a State-maintained route and the structure qualifies as a bridge or a stand-alone small structure replacement, the Design Division's Hydraulics Unit will furnish the required minimum size for both the flat-topped and the arch structure in the hydraulic recommendations letter. The designer will choose the most appropriate alternate for the structure layout scheme shown on the plans and reference, by note, the other alternate. If the Hydraulics Unit has not prepared a hydraulic recommendation, the designer will determine the hydraulic size for both alternates.

The hydraulic recommendations will include the Q_{100} elevation, the assumed flow line elevation, the required span and the required waterway opening for both structure alternates. The designer will select the rise of the structure for both alternates. The minimum desirable freeboard requirement will be 0.3 m for both an arch structure and a flat-topped structure with the low structure elevation determined at the structure centerline for both alternates. If the designer elects to use a freeboard less than that specified in the hydraulic recommendations letter, he or she should obtain the concurrence of the Hydraulics Unit supervisor. The flat-topped structure will be the only acceptable alternate if the freeboard is less than 0.3 m.

Where the required structure span exceeds 9.15 m, the Hydraulics Unit will also provide the required waterway opening for a spill-through bridge. The designer will size an appropriate bridge and perform an economic comparison between the bridge and the three-sided structure options.

The plans should show the structure size in meters to two decimal places, and the pay item designation should show the structure size in millimeters. The rise of the structure should be rounded to the nearest 100 mm.

73-2.02 Segment Configuration and Skew

Skew should generally be in 5-degree intervals, although 1-degree intervals are permissible where necessary.

It is not necessary for the designer to determine the exact number and length of segments. The final structure length and segment configuration will be determined by the fabricator and may deviate from that implied by the plans. However, a minimum horizontal clearance of 1.8 m must exist between the front face of guardrail and the outside face of the structure headwall where the drainage structure end is within the clear zone.

Square segments are generally more economical even if the structure is skewed. Laying out the structure with square segments will result in the greatest right-of-way requirement and thus allow ample space for any potential redesign by the contractor to another segment configuration.

For a structure with a skew of less than 15 deg, structure segments may be laid out square or skewed. However, skewed segments should be used for a structure less than 25 m in length, and square segments should be used for a longer structure. Skewed segments have a greater structural span. A skews greater than 15 deg will require special analysis per AASHTO *Standard Specifications for Highway Bridges* Section 17.8.5.3. Skewed segments and the special analysis both contribute to higher structure cost.

The layout scheme for an arch structure with a skew greater than 15 deg should assume square segments with a sloping top of headwall to yield the shortest possible wingwalls. For a flat-topped structure with a skew greater than 15 deg, structure segments should be laid out square. If hydraulic conditions dictate the use of a flat-topped structure only, the segments may be laid out skewed if the structure is relatively short.

A significant number of flat-topped structures are built with skewed segments, i.e., segments shaped like parallelograms. However, several INDOT structures have been redesigned to use only square segments. Where a flat-topped structure is laid out with ends parallel to the roadway, skewed segments are implied by the designer.

Where an arch structure is laid out with skewed ends (headwalls parallel to the roadway), the skew will be developed within the end segments by varying the lengths of the legs as measured along the centerline of the structure. The maximum attainable skew is controlled by the difference between the full segment leg length as recommended by the arch structure fabricator and a minimum leg length of 0.6 m.

If the roadway above the structure is to be constructed in two phases, the designer should propose a segment skew configuration compatible with the anticipated construction line between construction phases. Therefore, if the structure length is 25 m or greater, a unique special provision should be included to require the contractor to design and detail special segments or cast-in-place construction required to conform to the construction line between phases. These details should be reviewed by the designer when shop drawings are submitted.

73-2.03 Plan Requirements for Structure Layout and Detailing

The designer should select the most appropriate structure alternate for the structure layout scheme and show that alternate on the plans. The designer should use the span and rise for this alternate as a reference for the information required on the Title Sheet. The structure type to be shown on the Title, Layout, and General Plan sheets should be Precast Reinforced Concrete Three-Sided Structure.

The General Plan should include a note or a detail indicating that an alternate structure type with specified alternate span and rise dimensions may be substituted for the structure indicated in the layout scheme. Where a flat-topped structure is the only option permitted, the note should state that a three-sided arch structure will not be permitted at this location.

The designer should provide, on the General Plan or other detail sheet, the elevations as follows:

1. Q_{100};
2. flow line, at both structure ends and the roadway centerline;
3. fhe low structure at the centerline of the structure;
4. the tops of headwalls; and
5. the tops of wingwalls.

The assumed elevations of the top of the footing and the base of the structure leg should also be given. For structure layout purposes, a 0.6-m footing thickness should be assumed with the base of the structure leg seated 50 mm below the top of the footing elevation. With the bottom of the footing placed at the standard depth of 1.2 m below the flow line elevation, the base of the structure leg should therefore be shown as 0.65 m below the flow line. Exceptions to the 1.2 m depth will occur where the anticipated footing thickness is known to exceed 0.6 m, where the footing must extend to rock, or where poor soil conditions dictate that the footing be deeper.

The footing should be kept level where possible. If the stream grade prohibits a level footing, the wingwall footings must be laid out to be constructed on the same plane as the structure footings.

The designer should indicate the structure length and the flare angle, and the length and height of wingwalls. For a skewed structure, the wingwall geometrics should be determined for each individual wing. The side slope used to determine the wing length should be shown on the plans.

The pay length for a skewed structure should always be measured along the skew at the centerline of the structure.

The structure should extend to a point where the headwall height can be kept to a minimum, preferably 0.3 m. The structure should have headwalls with standard-length-post guardrail

protection provided unless the structure cover does not permit it. Where structure cover does not permit a standard headwall and standard-length-post guardrail installation, the designer should specify on the plans one of the options shown in the INDOT *Standard Drawings*. The designer must ensure that a minimum of 1.8 m of clearance exists horizontally between the face of guardrail and the outside face of the structure headwall.

For shallow cover of less than 500 mm and a structure width of greater than 7400 mm, the designer may elect to use a concrete barrier railing or type CF-1 bridge railing mounted on the structure headwall. Such railing should be shown on the plans with cast-in-place concrete and reinforcing steel detailed.

If the necessary height of the structure leg exceeds the commonly available leg lengths, the designer should show the required pedestal height in the structure elevation view. The fabricator will provide the pedestal design and details in the shop drawings or will specify longer than standard legs on the structure segments to provide the required rise. The pedestal height must be added to the precast structure leg length shown on the plans to determine the rise specified in the pay item.

The design and details for footings or base slabs, wingwall footings, wingwalls, and headwalls will be provided by the structure manufacturer when the shop drawings are submitted. The designer who prepared the contract plans will review the design calculations and shop drawings. For a federal-aid local agency project, such documents are subject to approval by the local agency or its design consultant.

The designer should refrain from showing details on the plans such as wingwall anchor systems that suggest a proprietary product. Such details should be shown on the shop drawings.

73-2.04 Foundations

The allowable soil bearing pressure should be shown on the plans. If the footing is on piling, the ultimate pile bearing load should be shown.

A table should be included on the plans listing the soil parameters for wingwall design as follows:

1. angle of friction between wingwall footing and foundation soil (∗);
2. angle of internal friction of the foundation soil (N);
3. ultimate cohesion of foundation soil (C); and
4. ultimate adhesion between foundation soil and concrete (C_A).

These soil parameters will be provided in the geotechnical report for the three-sided structure. If the geotechnical report is lacking this information, it should be requested from the Materials and Tests Division's Geotechnical Section.

Where a pile footing is required, the designer should determine the type and size of pile and the required pile spacing and show this information on the plans along with any piles that are to be battered. The final design of the pile cap will be performed by the fabricator and the details will be shown on the shop drawings as is the practice for other footing types. If the geotechnical report recommends piling be used, the designer should re-evaluate the structure type selection versus a spill-through bridge in light of the added expense of a pile footing.

The plans for three-sided structures should include a sheet showing the soil boring logs for the structure.

73-2.05 Backfill Requirements

The structure and wingwall backfill limits should be shown on the plans. The backfill limits should have a width of 0.45 m at the bottom of the footing and should extend upward at a slope rate of 1:4. The wingwall backfill should extend upward at 1:1 slope from the bottom of the wingwall footing. The structure fabricator will also be required to show the backfill limits on the shop drawings. The backfill pay limits should be based on the neat line limits shown on the plans.

Where there is less than 0.3 m of cover between the structure and the proposed pavement structure, the structure should be backfilled with flowable backfill. If an arch structure is specified, the flowable backfill should extend upward to the elevation of the outside crest of the arch. This elevation shall be designated as the fill line for flowable backfill. Compacted aggregate should be used between the flowable backfill and the underside of the proposed pavement structure. The Materials and Tests Division's pavement design engineer should be consulted for the minimum pavement thickness to use above the structure.

Riprap and geotextile should be used on the stream banks adjacent to the wings to stabilize and protect the structure backfill.

73-2.06 Scour Considerations

The designer must include either riprap or a concrete base slab to prevent significant scour from occurring. These requirements supersede the calculated theoretical scour requirements.

Riprap is the preferred method. The base slab method should only be used if the Design Division's Hydraulics Unit determines the hydraulics of the crossing to require a smooth flowline for a state-route project, the consultant determines such for a local agency project, or the span width is less than 3 m.

73-2.06(01) Riprap

The standard footing depth of 1.2 m below the flow line and the riprap protection as shown in the INDOT *Standard Drawings* will suffice most often for scour protection.

Figure 73-2A must be used to determine the riprap type required for a three-sided structure, bridge, or channel. The figure is intended for use with the riprap requirements shown in the INDOT *Standard Specifications*.

Once the riprap type is determined, the riprap quantities should be determined and then shown on the plans.

73-2.06(02) Concrete Base Slab

Where the allowable soil bearing pressure is extremely low, or where the stream velocity exceeds 3.0 m/s, the designer should provide a concrete base slab instead of a conventional strip footing. Details of the base slab method of scour protection are shown in the INDOT *Standard Drawings*. Where the allowable soil bearing pressure is marginally low, the designer should study the cost effectiveness of providing a base slab versus providing a strip footing with riprap scour protection. The input of district construction should be requested at the preliminary field check if the costs appear to be equal. The quantity of class B concrete must be shown on the plans.

73-2.06(03) Affects On Environmental Permits

If the Indiana Department of Natural Resources Floodway Construction, Indiana Department of Environmental Management Water Quality 401, or U.S. Army Corps of Engineers 404, permit application information has been given to the Design Division's permits coordinator, the designer must provide the additional quantities of riprap or concrete to the coordinator. The coordinator will incorporate the information into the permit application. If one or more of these permits has been granted, the designer must still provide the quantities information to the coordinator. The coordinator will then apply for a permit amendment.